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A study on influence of peak current and ultrasonic vibration during powder mixed electrical discharge machining process

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Abstract. This paper presents the influence of peak current and induced ultrasonic vibration into the dielectric medium during powder mixed electrical discharge machining (PMEDM) process. Molybdenum-di-sulphide powder of 90nm size is used as conductive particle mixed in hydrocarbon based dielectric medium during EDM process. Peak current is varied at 0.5A, 2A, 9A and 21A; parameters such as pulse duration 10µs, gap voltage 20V and duty factor 2 were maintained constant. Two set of experiments were conducted by varying peak current; one by induced ultrasonic vibration during PMEDM and another without ultrasonic vibration. The effect of peak current and ultrasonic vibration on material removal rate, surface roughness and crater diameter were analysed. Scanning electron microscope images and 2D roughness profile were used to analyse surface integrity. It is observed that the induced ultrasonic vibration improves MRR by 6 times, surface roughness (R_a) of 1.464 µm, small crater diameter and debris free surface is achieved.

1. Introduction

The materials with specific properties such as high corrosion resistance, resistance to chemical reactions, etc. possess increasing demand in automotive, marine and aerospace industry. Among those materials stainless steel is widely used in aerospace industry to manufacture landing gears and sliding components [1-2].

Electrical discharge machining (EDM) process is proven technology to machine the difficult-to-cut materials regardless of its mechanical properties of materials like high strength, high hardness. This technology extensively used for machining intricate cuts or shape, dies and tools, micro engine parts in aerospace, automotive and manufacturing industry [3]. In EDM process material removal mechanism, through the formation of plasma channel across the tool electrode and work piece, bring about melting and evaporation of the workpiece material [4, 5]. However, the performance of the EDM is low and also it generates poor surface finish that restricts its further application. To solve this problem, a relatively new method is developed by mixing conductive powder particles in dielectric medium named as powder mixed electrical discharge machining process (PMEDM) [6]. Many researchers have studied the behavior of mixing powder particles like SiC, Ti, Mo, CNT, Al_2O_3 in dielectric medium and studied EDM performance [7]. Harmesh kumar et al. [8] examined on machining of AISI- D2 steel by varying peak current and pulse duration using CNT powders mixed in dielectric medium. By adding CNT powder concentration at 4 g/l, material removal rate (MRR) improved by 80% and surface roughness reduced by 67 %. Marashi et al. [9] explored on surface characteristics of AISI D2 steel machined using Ti-Nano powder mixed in dielectric medium during

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PMEDM process. The experimental results reveal that, surface finish improved by 69 % and 35 % for the peak current of 6 A and 12 A respectively. Prihandana et al. [10] studied on the influence of molybdenum disulfide powder mixed into dielectric medium to produces the high quality micro-holes and stated, for powder particle with 50 nm size and 5 g/l of concentration, high MRR is achieved. Santosh kumar et al. [11] attempted to study the machining characteristic and surface integrity of Inconel 718 super alloys by addition of SiC powders in dielectric medium during PMEDM process. The machined surface exhibited better surface morphology in terms of deposited debris, pock marks, micro cracks as compared to the conventional EDM process. Shabgard et al. [12] conducted a series of experiments to explore machining characteristics of Ti-6Al-4V using ultrasonic tool vibration and found that ultrasonic frequency enhances the machining stability by reducing open and short circuit pulse. Abdullah et al. [13] studied the influence of ultrasonic vibration on machining characteristics of cemented tungsten carbide material and proposed that, the ultrasonic vibration improves machining performance at finishing regimes.

Literature reveals that authors have explored the effect of mixing conductive powder particles in dielectric fluid and its effect of EDM performance. Also, a limited work has been carried out using ultrasonic vibration during powder mixed electrical discharge machining. The objective of this paper is to investigate the effect of peak current and ultrasonic vibration on material removal rate and surface integrity of AISI 304 steel material machined using molybdenum-di-sulfide (MoS_2) powder mixed EDM process.

2. Experimental procedure

Experiments were carried out on SMART- S 50 ZNC die sinking electrical discharge machine which operates with iso-pulse generator. A separate experimental setup is developed to conduct experiments using ultrasonic assisted PMEDM as shown in figure 1. Pure copper of 8 mm diameter is selected as tool material and AISI 304 stainless steel of 100 x 100 x 10 mm as the work piece material. The chemical composition of workpiece material is given in table1. During experimentation; the tool electrode is connected to positive polarity and work piece to negative. Molybdenum-di-sulfide (MoS_2) of 90 nm size is selected as powder material. The property of MoS_2 nano powder is given in table 2. From literature it is observed that among various EDM process variables, peak current show dominant effect on MRR and surface morphology. Also, the induced ultrasonic vibration promotes MRR and surface finish. Therefore, in this work peak current is selected as input parameter and is varied at 0.5, 2,9 and 21 A, keeping pulse duration 10 µs, gap voltage 20 V, duty factor 2 and MoS_2 powder concentration of 1 *g/l* constant. To understand the influence of ultrasonic vibration on MRR and surface finish, two sets of experiments are planned. One set of experiments were conducted by induced ultrasonic vibration to dielectric medium in PMEDM (UAPMEDM) and another with PMEDM (without ultrasonic vibration to dielectric medium). For all experiments, the machining time is kept constant as 30 minutes. Table 3 shows the input process parameter conditions used during experiments. The influence of these input parameters on output parameters like material removal rate, surface roughness (R_a & R_t) and average crater diameter (d_c) taken as the output variables are analysed. The MRR (mg/min) is calculated by knowing the machining time (t_m) and mass of work piece before machining (w_i) and after machining (w_f) using equation (1) as

$$MRR=\frac{w_i-w_f}{t_m} \tag{1}$$

A weighing machine of 0.1 mg accuracy is used to measure the mass of the work piece before and after machining. The surface roughness is measured using 2D- profilometer (“MarSurf GD 120”). Scanning electron microscopy (SEM) is used to measure crater diameter. For each specimen the surface roughness and crater diameter are measured at three different locations and its average value is presented in table 3.

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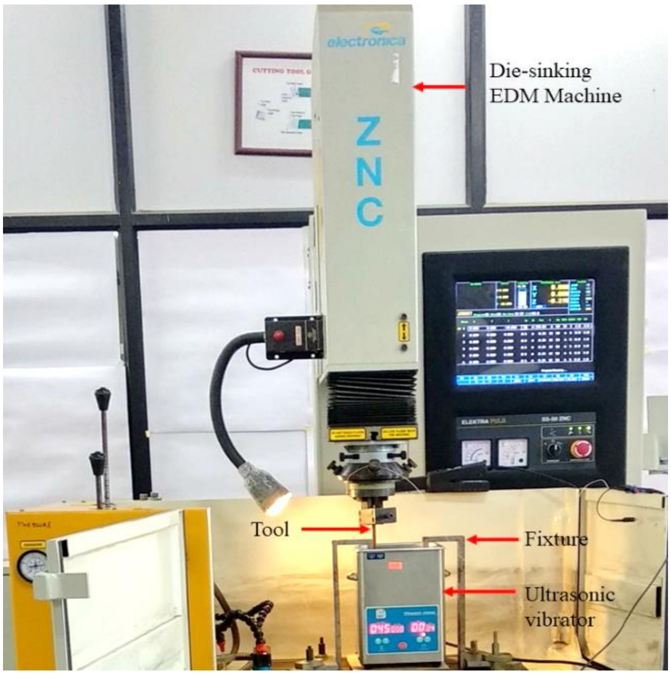

Figure 1. Experimental setup for powder mixed Electrical discharge machining.

Table 1. Chemical compositions of (weight %) of AISI 304 Stainless steel.

AISI 304	%C	%Mn	%S	%P	%Si	%Ni	%Cr	%N	% Fe
Min- Max	0.07	2	0.03	0.045	0.75	8.0-10.5	17.5-19.5	0-0.10	≥67

Table 2. MoS_2Nano powder properties.

Manufacturer	Sisco Research Laboratories Pvt. Ltd.
Molecular weight	160.07 g/mol
Average particle size	90 nm
Density	5.06 g/cm^3

3. Results and discussions

3.1. Material removal rate (MRR)

The influence of peak current on material removal rate is shown in figure 2. As the peak current increases, MRR increase in both PMEDM and UAPMEDM. High peak current leads to melting of more material that resulted in high MRR [14]. It is observed that, the induced ultrasonic vibration increases MRR compared to that machined without ultrasonic vibration. The induced ultrasonic vibration assist in efficient removal of debris particle that resulted in increased MRR. Also at peak current 2A, MRR obtained in UAPMEDM is nearly 6 times higher than PMEDM process. The

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ultrasonic vibration promotes improved debris removal from the gap and better dielectric fluid renewal that resulted in increased MRR [13].

Table 3. Influence of peak current and ultrasonic vibration on machining characteristics of AISI 304 stainless steel.

Exp. No	Peak Current (A)	Pulse duration (μs)	Gap voltage (V)	Duty factor	Material Removal Rate (mg/min)	Surface Roughness (μm)		Average Crater diameter (μm)
						R_a	R_t	
UAPMEDM								
1	0.5	10	20	2	0.300	1.464	12.6839	32.876
2	2				1.833	2.605	19.7764	37.419
3	9				6.967	3.458	29.0208	81.521
4	21				24.433	4.180	30.7219	114.766
PMEDM (without ultrasonic vibration)								
1	0.5	10	20	2	0.233	1.459	12.0689	24.109
2	2				0.300	2.581	18.6209	33.894
3	9				6.767	3.338	27.0449	90.878
4	21				24.233	4.344	32.6312	136.183

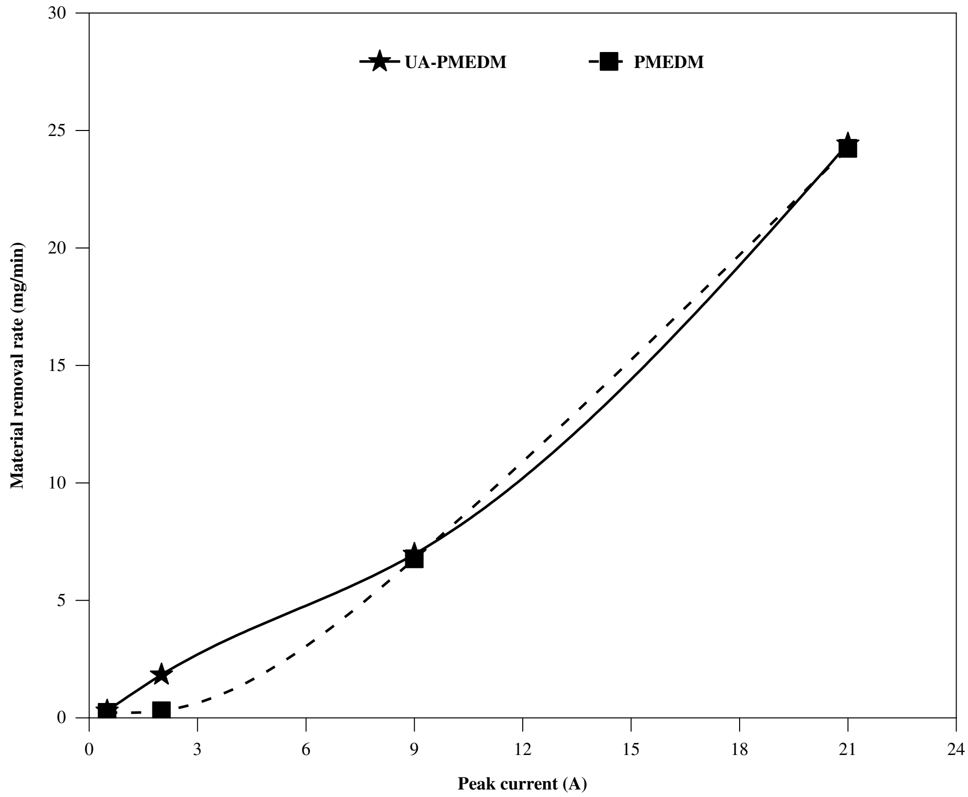


Figure 2. Influence of Peak current on material removal rate.

3.2. Surface roughness

The impact of peak current and ultrasonic vibration against surface roughness (R_a and R_t) is shown in figure 3. The experimental results show that surface roughness increases with increase of peak current. At low peak current (0.5 A), minimum surface roughness is achieved in both UAPMEDM and PMEDM process. At low peak current magnitude, the energy per pulse is low that the melted material gets re-solidified back on to machined surface generating surface with better surface finish. This can be observed from the 2D roughness profile as shown in figure 4 (a-b). At high peak current magnitude

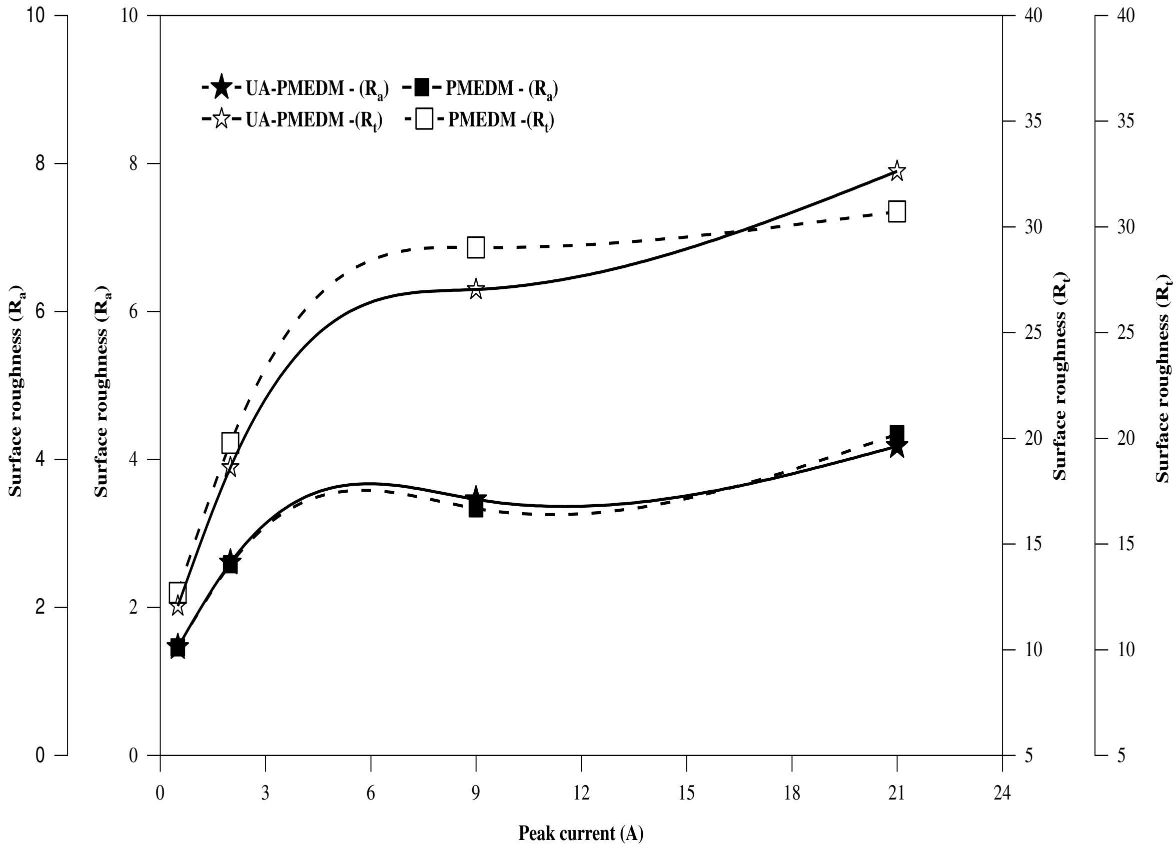
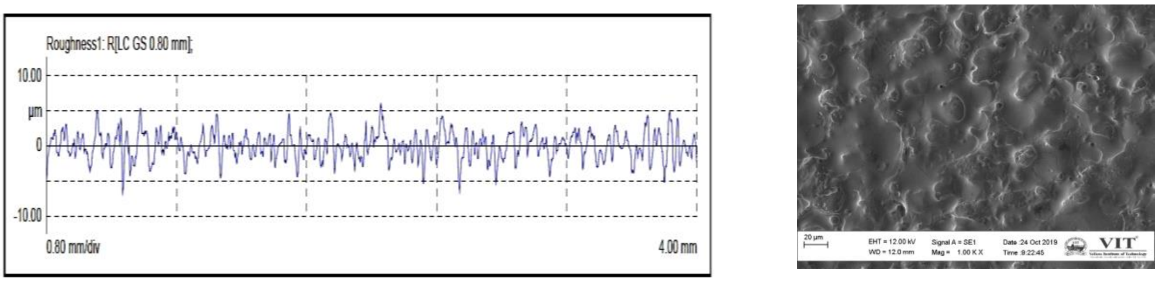


Figure 3. Influence of peak current on surface roughness.

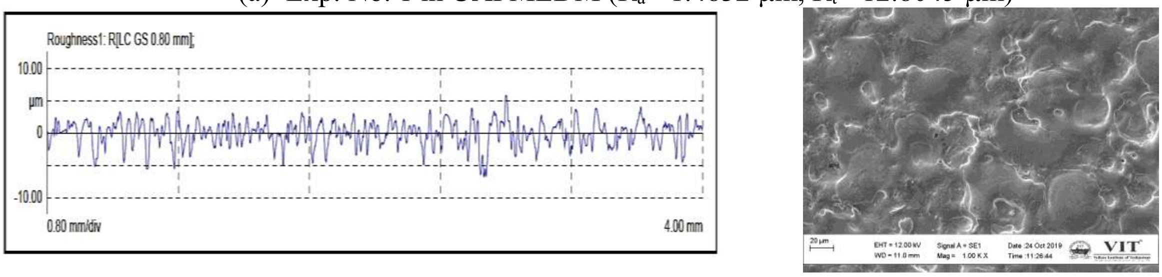
the increased erosive power per pulse removes more material from work piece surface [5]. This resulted in increased surface roughness in both UAPMEDM and PMEDM process as shown in figure 4 (c-d). The 2D roughness profile of machined surface reveals that the maximum height of profile (R_t) is 28.6534 μm and 32.1610 μm for UAPMEDM and PMEDM respectively. The induced ultrasonic vibration to dielectric medium, promotes better flushing of debris particle in the gap and that resulted in reduced height of profile. Scanning electron microscope (SEM) image taken at magnification of 1000X reveals the variation in machined surface for different current magnitudes.

3.3. Average Crater diameter(dc)

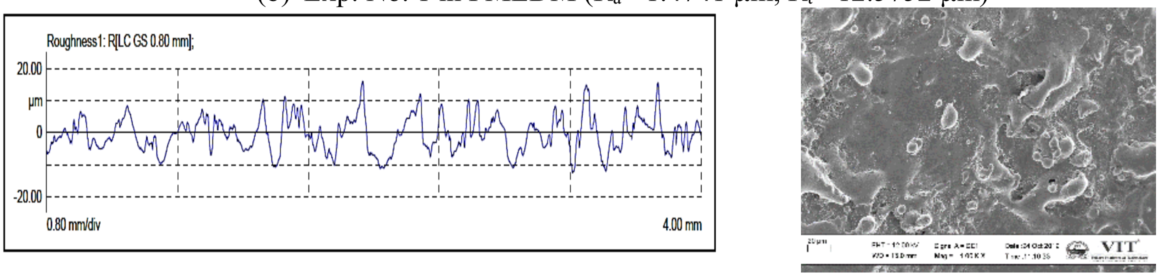
The influence of peak current and ultrasonic vibration against average crater diameter is shown in figure 5. As the peak current increases, the energy per spark increase which generates the wider and deeper crater [15]. The experimental result show that, the crater diameter increases with increase in peak current for both UAPMEDM and PMEDM process. At low current magnitude (2A) powder mixed EDM produce small diameter crater compared to that of UAPMEDM as shown in figure 6 (a-b). At high current magnitude (9A) ultrasonic assisted powder mixed EDM generates small diameter crater compared to that of PMEDM as shown in figure 6 (c-d). At 2A peak current, the induced ultrasonic vibration has less significant effect on crated diameter. At high current magnitude the induced ultrasonic vibration in dielectric medium, restricts the expansion of compressed vapour bubble that resulted in reduced crater diameter as shown in figure 6.



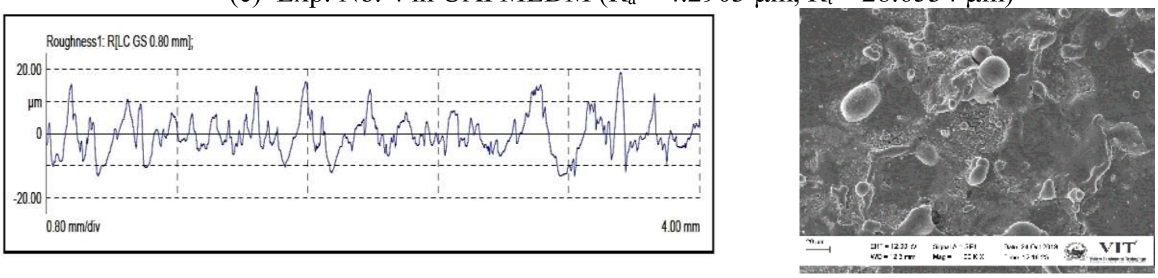
(a) Exp. No. 1 in UAPMEDM (R_a - 1.4832 µm, R_t - 12.8045 µm)



(b) Exp. No. 1 in PMEDM (R_a - 1.4741 µm, R_t - 12.5752 µm)



(c) Exp. No. 4 in UAPMEDM (R_a – 4.2903 µm, R_t – 28.6534 µm)



(d) Exp. No. 4 in PMEDM (R_a – 4.6393 µm, R_t – 32.1610 µm)

Figure 4. Influence of ultrasonic vibration on surface roughness for peak current 0.5 A [(a)-(b)] and 21 A [(c)-(d)].

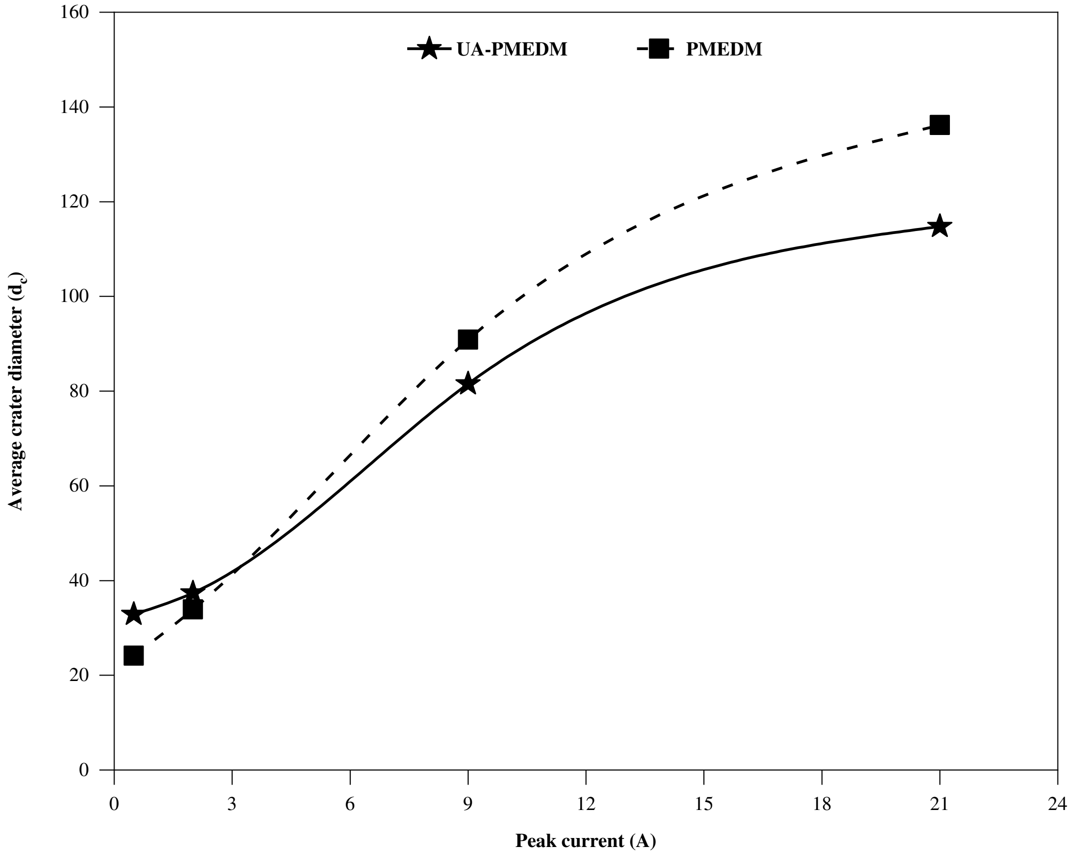
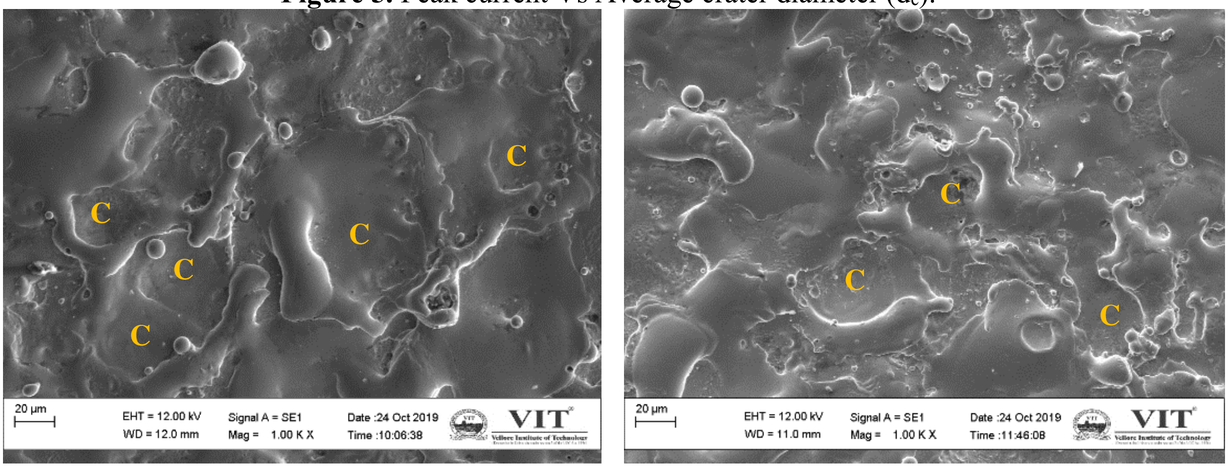
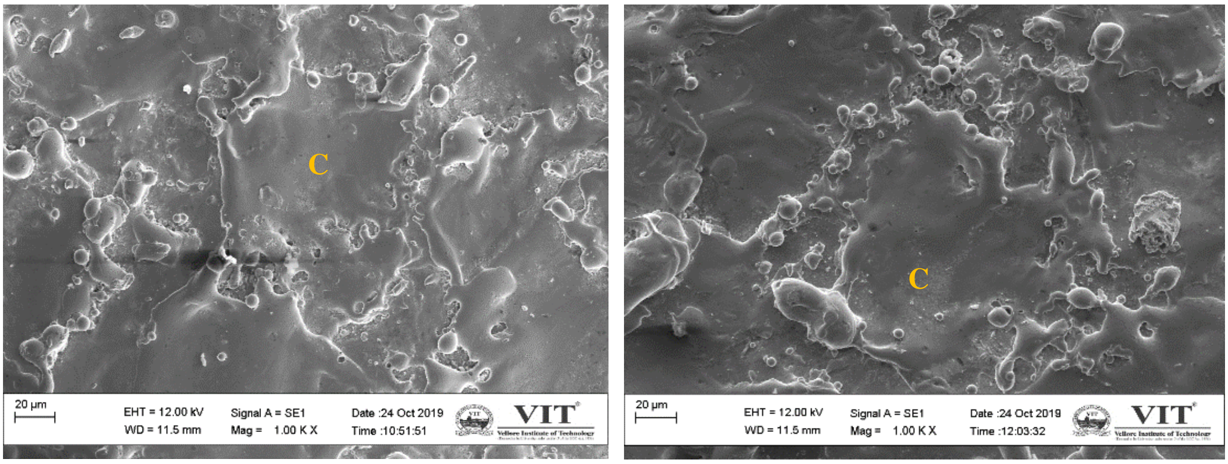


Figure 5. Peak current Vs Average crater diameter (d_c).



(a) UAPMEDM – 2 A (dc – 32.87 µm) (b) PMEDM – 2 A (dc – 24.11 µm)



(c) UAPMEDM – 9A (dc – 114.76 µm) (d) PMEDM – 9 A (dc – 136.18 µm)

Figure 6. Influence of peak current and ultrasonic vibration on crater diameter (C - crater).

4. Conclusions

The influence of peak current and ultrasonic vibration on machining characteristics of AISI 304 stainless steel using MoS_2 nano powder mixed EDM process is analyzed. The peak current is varied at 0.5A, 2A, 9A, 21A keeping pulse duration 10µs, gap voltage 20V and duty factor 2 constant. The experimental results reveals that, material removal rate increases with increase in peak current for both UAPMEDM and PMEDM process. At peak current values (2 A), the MRR in UAPMEDM is nearly 6 times higher than the PMEDM. Increase the peak current magnitude, surface finish gets worsened in both UAPMEDM and PMEDM. As the peak current increases the erosive power of pulse increase, which resulted in increased surface roughness. However, at peak current of 21A the improved height of roughness profile obtained in UAPMEDM compared to that of PMEDM. The diameter of crater increases with increase in peak current.

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